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# THE MODULUS OF LUNAR INFLUENCE, NOT IN A LIFTING, BUT IN A FALLING MOVEMENT.

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IN the opinion of the writer, there is a general misconception of the immediate cause of the phenomena of the semidiurnal oceanic tides. I approach the subject very directly, that its discussion may not extend this paper beyond proper limits.

The usual explanation of the *modus operandi* of the moon's influence is very unsatisfactory to the ordinary inquirer, and especially that part of it which attempts to account for the tidal flow opposite the prolunar side of the earth. Perhaps the failure of the scientific expositors is due to a mistaken impression of how the moon's power is applied. The most important vantage is discarded or neglected. The pulling of the moon upon the waters of the prolunar geohemisphere is assumed to be the main cause of the tidal wave on that side of the earth, the sun coming in as an adjunctive or diversive agency, as the case may be. On the opposite hemispere the marine proturbance results from the unequal pull on the ocean bottom and the ocean surface, or, as some express it, by a pulling away of the land from the waters, "as it were," as a qualifying phrase, which, to use another metaphor, is putting the proposition into a ruminant's paunch for subsequent mastication. It is difficult to conceive the power thus attributed to the moon as really operative, while our senses give no indication of it in our physiological experience. It is still more difficult for the student to mentally perceive how the land and sea are pulled apart on both sides of the globe simultaneously.

I will endeavor to show a cause of tides more powerful than the moon's direct action, and the operation of which can be more easily comprehended, existing within the compass of the earth, and subject to the laws of gravity. The tendency of concrete bodies to approach each other is proportioned to the sum of their masses, modified by the spatial degrees of separation, diminishing as the latter increases, and augmenting as it declines in proportion to the square of any lineal unit or units of measure. That is to say, if their distance apart is doubled, the gravitational force is reduced to one-fourth its previous power; but if the original distance is reduced to one-half, the power is increased fourfold. Now, in spheres, if the mass is distributed symmetrically, the center of gravity will be the center of the sphere, but if unsymmetrically, the gravity center will be eccentric with reference to the spherical center. The latter relation exists in the moon. But this incoincidence has no dynamic effect in a non-rotating sphere. In a rotating sphere this incoincidence becomes a very important source of dynamic action. The internal mass is constantly impelled to adjust itself symmetrically concentric to the middle point of the axis of rotation. The movements of adjustment engender heat, intense in dense matter, and are continuously and eternally operating while equilibrium is unsatisfied. This a law of gravity, everlasting, invariable, and instantaneous in action. The earth's center of gravity is, therefore, the central point of its axis of rotation.

The ratio of the moon's mass to that of the earth has not been certainly determined, but is assumed to be about as one to eighty, a convenient one to use in this connection. The geolunar gravity center is near the center of the earth. It would be if the two planets were in contact, but by reason of the distance of the eighty-first part from the main mass it is nearer. It is a constantly changing point, and the earth's center revolves about it monthly, at a varying distance regulated by the moon's perigee and apogee positions.

In an old edition of Burritt's Astronomy, a popular work forty to fifty years ago, the geolunar gravity center was placed at about 3000 miles from the earth's center. But this assumed distance seems to have been suggested on the principle of the steelyard. In modern works of astronomy and physics which I have consulted, but little reference to this important focus is to be found. That it must be near the earth's center is evident or the mensal revolution about it would be a very obvious and remarkable phenomenon in astronomical observations. But it is certain that it cannot be coincident or identical with the terrestrial center; if this were the case there would be no tides. Now, this eccentric destroyer of equilibrium cannot be eliminated by any rearrangement of the earth's materials, because it is a continually shifting point westward, northward, southward, centripetally and centrifugally. Yet it is the point towards which all the earth's substances are constantly pressing, keeping up an incessant churning of the fluid interior already under pressures of 2,000,000 to 3,000,000 atmospheres. The heat engendered must be beyond calculation, and it is not extravagant to suppose that gases as dense as metals on the surface mingle according to the law of gaseous diffusion. And yet this heat is not equivalent to what escapes from the surface, as shown by the continued contraction of the crust. As we go from the center outwards the intensity of influence becomes rapidly less in proportion to the squares of distance from the heart of turbulence. The severity of action in the interior is due to the extreme influence of mass relative to volume from pressure, to the nature of its elements and to the comparatively great differences in distances between the geolunar gravity center and the various parts of the indeterminate core. A little way from this fountain of agitation the ratios of distance are much reduced, and at the surface are quite small. The tides are the last obvious phenomenon, the tail, indeed, of the moon's interference with mundane equilibrium. I say "obvious phenomenon," though, as a matter of fact, the petrosphere is subject to continuous vibrations, discernable at seismographic stations, similar to those affecting the most massive bridges under the strain of footsteps, moving vehicles, and winds. And the atmosphere gives some indications of response to the tumult of the centrosphere, but owing to its elasticity no perceptible movements of its matter can be traced with certainty to that cause.

I will now attempt to make clear the working of the tides, beginning with the aplunar geohemisphere, or that hemisphere farthest from the moon. The point on the surface of the ocean directly in line with the geolunar gravity center and the moon is the highest on the hydrosphere, because it is the most remote from that center. It is common observation that water "runs down hill." No fact in nature is better established as a matter of positive knowledge, and every grammar-school boy can tell why. He knows that all fluids seek a position not occupied by something heavier, nearest the center of gravity, generally regarded as the center of the earth, but really the geolunar gravity center. The flowing fluid is said to be seeking its level. This is what the waters of the ocean do; they seek a level, an equilibrium. In every direction they flow from this high point towards a lower one. If the high point were fixed it would soon vanish, for the water would attain its level and there would be neither high nor low point

Only the westward and the eastward retreat of the waters from the high point need be considered with reference to tidal action in general. The water seeking its level westward exerts its weight contrary to its rotational motion, and the latter is slowed; that seeking its level eastward, in the direction of rotation, accelerates its own velocity. The eastern land coasts of the continental areas with undiminished velocity collide with the west flowing, or retarded, water, and bury themselves in its breast, and this process produces the tidal phenomenon of the eastern coasts. On the other hand, the accelerated eastern flow, striking the normally moving west coast lands, rushes over them and drowns them in its billows. Thus we have on one side the land plowing into the sea, and on the other the sea overwhelming the land.

Now, let us investigate the situation on the prolunar geohemisphere. Directly under the moon and exactly opposite the high point is the lowest spot on the face of the hydrosphere, which covers nearly three-fourths of the spherical area. It is the lowest because it is the one nearest the geolunar gravity center. It is the one spot toward which all the waters of the hemisphere are flowing in seeking their level. The waters to the west of it, flowing eastward, are the accelerated waters; those to the east, flowing westward, are the retarded waters; but they sustain the same relations to the coast-lines as on the other hemisphere. If we now connect the two hemispheres and trace the tidal sweeps from one to the other we find continuous flows from the high point to the low point, starting in opposite ways. The waters of the ocean are seeking their level precisely as the rivers do; as, for instance, the Sacramento and the San Joaquin, of California, from the northwest and southeast, respectively, find their level in the bay of San Francisco.

It is well known that water does not move as a solid body does—at the same rate of motion throughout its mass—but some parts move swifter than others, the free surface having lesser friction to overcome, and the deeper and denser, the greater, give to the visible current a rolling appearance; hence we habitually and correctly speak of the rolling wave, the rolling river, as "the flow of Isar rolling rapidly." In the tidal wave there is always a thin, wedge-shaped advanced stratum in front of the main mass, and a like stratum lagging at the origin of the flow. We may call the high and the low points described above the tidal poles. It is at these poles that the moving floods are most shallowed, and midway between that they are most thickened. When the poles pass the coasts, or, rather, when the coasts pass the poles, at the velocity of about 14½ degrees an hour, it is the extreme of ebb, and when they pass the midway points it is the acme of flood.

We may now consider the direct influence of the moon upon the earth's surface, without regard to the geolunar gravity center. If the moon's center were within 4000 miles of the earth's surface, the influence of the satellite upon the hydrosphere would be in the ratio of its mass to that of the earth's, and a pound normal of 7000 grains would be diminished in weight about 87 to 88 grains on that spot of the prolunar hemisphere directly under the satellite; but being 60 times as far distant, its power is but $\frac{1}{3600}$ of what it would be in the assumed position; and if we allow its counterbalancing effect on the normal avoirdupois pound as $\frac{1}{40}$ of a grain, we make a very liberal concession. This is a ratio of 1 to 280,000 compared with the earth's influence in weight making. With this vast difference in degrees of ponderal powers, it seems like the shadow of a metaphor to attribute a capacity to our great sunlight reflector to pull up from the normal level millions of tons of water in opposition to nearly 300,000 times its own potency. But what we speak of as the subtrahend of terrestrial weight, or the pulling force of the moon, is really but an index of the tendency of the water to leave the earth and go to the moon, an impulse inherent in the water itself and not in any extrinsic pulling force, and which, measured by its tendency to remain, is as 1 to 280,000. It is true there must be a differential in degrees of tendency between surface waters and deep layers, but this is too slight to produce an observable effect. If a pulling power would draw the waters toward the eastern shores, it would draw them away from the western shores, and the tides there would be but the effect of their returning to the normal. It may be possible to measure mechanically with a torsion fiber and a long index finger over a large dial the supposed power of the moon. I am not aware that the attempt has been made. It would be a great triumph of skill and science, if successful.

Yet in that case how could the effect of the approach of the geolunar gravity center to the sublunar terrestrial surface be excluded from the elements entering into the difficult experiment and its results? Unfortunately the dynamics of the tides have been made a datum for calculating the moon's mass, with a likelihood of having derived too large a quantity as a conclusion. It is quite possible, if not probable, that its ratio of mass to that of the earth's is not even 1 to 100, instead of 1 to 80. If the satellite is an offspring of the earth, which appears a very proper inference from what we know of cosmic physics of solar action and extraplanetary conditions, it was born when our globe had a gaseous or liquid constitution from center to circumference, and was much more oblate than at present, and must be mostly composed of the lightest metals and metalloids. Nor is it probable that since that time it has ever enlarged its orbital circuit—on the contrary, it is more likely to have contracted it, for reasons which are given in another paper.

The action of the sun in gravity work is all direct, for the geosolar gravity center is in the body of that governing fire-ball, and so of all the intra-Jovian planets, and, probably, of all the others. It may be that the planets themselves are responsible for much of the heat they receive from the sun, for the numerous eccentric gravity centers in that revolving and rotating star must cause an agitation and disruption of its entire constitution, with evolution of heat. This is no fanciful conjecture of what *may* be, but a certain result of admitted gravitational law.

Turning to the question of the moon's influence to affect the length of the siderial day, we have seen that the tides are mainly caused by the eccentricity of the geolunar gravity center to the purely terrestial center and the axis of rotation, and to rotation itself, and that the moon's direct influence is simply a slight abatement or augmentation, as the case may be, of the normal weight of terrestrial matter; in either case producing no result not offset by a counter result. Unless it can be shown that purely secular redistributions of matter, such as come from trade-winds and ocean currents, have an effect to check rotational velocity, we may dismiss the idea that the moon does.

The premises and chief corollaries of the theorem may be summed up in the following propositions:

The geolunar gravity center is the point which all the matter of the earth presses to attain.

It is eccentric to the axis of rotation and to the earth's center of gravity.

It is a constantly shifting point, thereby causing a perpetual churning of the earth's fluid or plastic matter in its efforts to distribute its masses in equilibrium concentric to it, evolving heat.

It affects the fluids of the exterior less than those of the interior, conformable to the second Newtonian law of gravitation.

The oceanic tides result from the same influences that cause the interior clash, and are essentially waterfalls of vast extent, intercepted by sections of solid crust above or slightly below the normal sea surface.

The direct influence of the moon only feebly effects the normal ponderal relations of terrestrial matter, and does not retard terrestrial rotation.

The solid, brittle upper strata of the earth's crust, lined below by the semiplastic and plastic cushions of mixed material, are affected to continuous vibrations of very mild degrees.

A concluding thought is this: We are indebted to the moon for a habitable globe to-day. Without its existence as a heat producer in disturbing subterranean tranquillity, the earth ere this would have become a cold, solid, asymetrical, non-rotating spheroid. It is impossible that a large composite body of fluid become solid from loss of heat and retain symmetrical distribution of mass about its center of figure. Some parts or segments of the same radial distance from the center, and in the same plane parallel to the equator, will cool sooner than the remaining segments similarly situated, and from various causes, and asymmetry will follow. With asymmetry and complete solidity rotation must cease, as in the cases of Mercury, Venus, the moons, and the asteroids. Wherever we find a planet with a moon, or with moons, we may infer a rotation and a fluid interior, and with moonless planets the absence of both.